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APPLICATION NOTE

Microcomputers–What They Mean to Your Company

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Introduction

Microcomputers are a new extension of computer technology which offer users exciting possibilities for creating new products and services. Engineers are becoming more aware of the ways in which microcomputers can be applied to solve their problems. However, there is still very little understanding of the profound effects a microcomputer can have on corporate profitability and the ability of corporations to compete effectively in the market place. To many corporations the early application of microcomputers has enabled them to increase both their market share and profitability. There are five basic reasons why so many companies have begun to use microcomputers. These are:

1. Manufacturing costs of products can be significantly reduced.
2. Products can get to the market faster providing a company with the opportunity to increase product sales and market share.
3. Product capability is enhanced allowing manufacturers to provide customers with better products which can frequently command a higher price in the market place.
4. Development costs and time are reduced.
5. Product reliability is increased which leads to a corresponding reduction in both service and warranty costs.

These advantages and benefits accrue to the microcomputer user basically because the microcomputer enables the engineer to easily substitute programmed logic for conventional random logic networks designed with integrated circuits. Effectively, in a microcomputer system, the information about logical sequences and the output responses the system will generate to input signals are stored in memory instead of in relatively expensive interconnect patterns on printed circuit cards. In order to better comprehend how the microcomputer affects a corporation, one should first understand how memory can be used to replace logic.

How Memory Replaces Random Logic

If microcomputers were fast enough, all logic could be programmed. For this reason, as the speed of microcomputers is increased, more and more applications and designs implemented with conventional ICs are potential applications for microcomputers. The microcomputer replaces logic by storing program sequences in memory rather than implementing these sequences with gates and flip-flops. While it is impossible to prove with scientific certainty, interviews with numerous engineers confirm that designers are able to replace a gate by using 8 to 16 bits of memory. In other words, 8 to 16 bits of memory are the logical equivalent of a single gate. If we assume that the type IC used today contains on the order of 10 gates, then one can conclude that logic can be stored in memory in a very cost effective fashion. TABLE I indicates the number of ICs which are replaced by a single ROM (Read Only Memory). The table was derived by using the assumptions that 8 to 16 bits of ROM replace a gate and that on the average an IC contains 10 gates.

IC REPLACEMENT USING ROM's

ROM MEMORY SIZE BITS	GATES REPLACED	IC's REPLACED
2048	128-256	13-25
4096	256-512	25-50
8192	512-1024	50-100
16384	1024-2048	100-200

TABLE I—Number Of IC's Replaced With A ROM (Read Only Memory)

The reader is now in a position to understand how microcomputers can reduce product manufacturing costs.

Reducing Manufacturing Costs

If the burdened manufacturing cost of a digital electronic system is divided by the number of ICs, one generally finds that the system costs between $2 and $6 per IC to fabricate. The higher costs are generally associated with systems manufactured in volumes from 10 to 100 units annually. TABLE II presents a more detailed analysis of the source of these surprisingly high costs. The costs, themselves, are stated conservatively.

IC	.50
INCOMING INSPECTION	.05
PC CARD	.50
FABRICATION	.05
BOARD TEST AND REWORK	.10
CONNECTOR	.05
DISCRETERS	.05
WIRING	.10
POWER	.10
CABINETRY, FANS, ETC.	.10
	1.60

TABLE II—System Manufacturing Costs Per IC

The ASP (average sale price) of an Integrated Circuit today is approximately 50¢. Incoming inspection and testing of these ICs costs the average company 5¢. However, many companies are now buying aged and tested circuits for their applications in order to increase system reliability. This adds about 15¢ to unit costs. Simple PC cards may cost as little as 25¢ an IC position, but the average cost in most applications for high quality cards is closer to 50¢. Sophisticated multilayer cards used in many high performance systems frequently cost *over a dollar a position*. When customers put ICs in sockets and then wire wrap cards, the cost per IC position quickly approaches $2. Customers with automatic IC insertion equipment and efficient flow soldering machines can fabricate a PC card for as low as 3¢ an IC position, though the average price is closer to 5¢. Board test and rework add another dime to system cost, while the cost of a connector divided by the number of ICs per printed circuit card frequently exceeds 5¢. In general, resistors, capacitors, power bus bars, etc., add a cost of 5¢ an IC position. Systems frequently average one wire or more per IC position and the wires put in with automatic equipment frequently cost over 10¢.

Finally, the cost of power supplies and mechanical packaging add another 20¢ an IC position. TABLE III shows the potential dollars of system manufacturing cost which can be achieved by using a microcomputer. It is derived by assuming that the typical manufacturer can save between $1.50 and $3.00 by displacing a single IC. To determine the total savings in system manufacturing cost, the user must subtract the cost of implementing an equivalent system with a microcomputer. In moderate volumes, a system such as the MCS-4 with 16,384 bits of ROM, a processor, and a minimal amount of RAM can be purchased for under $100. This system has the potential of displacing between $150 and $600 of system manufacturing cost.

ROM MEMORY SIZE BITS	IC REPLACED	DOLLARS SAVED
2048	13-25	$19.50-$75
4096	25-50	$37.50-$150
8192	50-100	$75.00-$300
16384	100-200	$150.00-$600

TABLE III—Savings In Using Programmed Logic

The potential dollar savings can be immense. Customer estimates of savings in the electronic portion of their system range from 20% to 80%.

Surprisingly enough the economic benefits of using microcomputers are frequently not the dominant motivating force which leads to their application. One of the major reasons for the increasing popularity of these devices has to do with the speed with which products can be designed and delivered to the market.

Reducing Development Time and Cost

Microcomputers simplify almost every phase of product development. Because of the extensive design aids and support supplied with microcomputers, it is relatively easy to develop application programs that tailor the device to the system. One of the most significant contributions made by the microcomputer is that numerous customers are now willing to standardize on a microcomputer to solve their problems. Therefore, microcomputer manufacturers can invest millions of dollars in developing software and hardware design aids which will reduce customers' development cost and time.

Discussions with customers frequently uncover the fact that they have cut development cycles by as long as six to twelve months. TABLE IV tabulates a number of the steps in a customer's development cycle and indicates how the microcomputer can affect them. Surprisingly, product definition is frequently speeded up once the decision has been made to use a microcomputer. This is because the incremental cost for adding features to the system is usually small and can be easily estimated. For example, added features such as automatic tax computation for an electronic cash register may only require the addition of a single ROM. The addition of one LSI chip has a minimal effect on total system cost, power and packaging requirement. On the other hand, the same function implemented with IC logic might require two or three fairly large PC cards filled with MSI and SSI.

System and logic design time is also reduced. When the engineer decides to use a microcomputer, he does his design through programming. Programming is a faster way to design than using logic diagrams. Extensive software aids such as simulators, assemblers, editors, compilers and monitors reduce the cost of program development. These same aids also reduce the time for system debugging. PC card layout time is reduced simply because there are fewer cards to layout. This reduction in hardware also reduces the load on the technical writers who must develop maintenance manuals. Parts lists become shorter, easing the task of transferring the product to manufacturing. Cooling, packaging and power distribution problems frequently become trivial. Finally, engineering changes that are difficult to make and frequently tedious to document, become simple program changes. These can be made by changing the pattern in a ROM or PROM (Programmable Read Only Memory such as an Intel 1702A).

Thus, design becomes easier, faster and less costly and companies are discovering that the productivity of their engineering staffs can be increased. Subsequently, the best engineers can participate in more development projects.

Products Can Get to the Market Faster

If product design cycles can be shortened, it is obvious that new products can get to the market faster. This permits companies to either beat competition to the market or more effectively respond to competitive moves. Fig. 1 shows what typically happens in a com-

	CONVENTIONAL SYSTEM	PROGRAMMED LOGIC
Product definition		Simplified because of ease of incorporating features
System and logic design	Done with logic diagrams	Can be programmed with design aids (compilers, assemblers, editors)
Debug	Done with conventional lab instrumentation	Software and hardware aids reduce time
PC card layout		Fewer cards to layout
Documentation		Less hardware to document
Cooling and packaging		Reduced system size and power consumption eases job
Power distribution		Less power to distribute
Engineering changes	Done with yellow wire	Change program in PROM

TABLE IV—How Development Time and Cost are Reduced with Microcomputers

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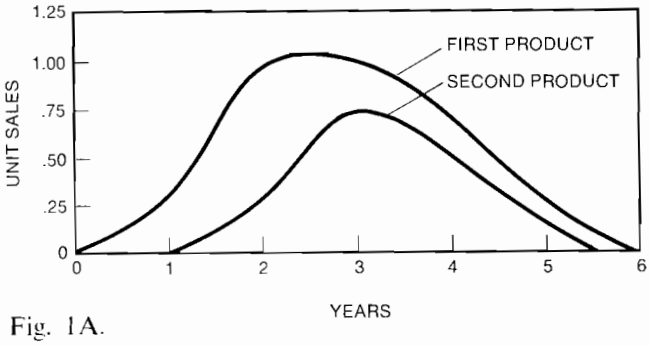

Fig. 1A.

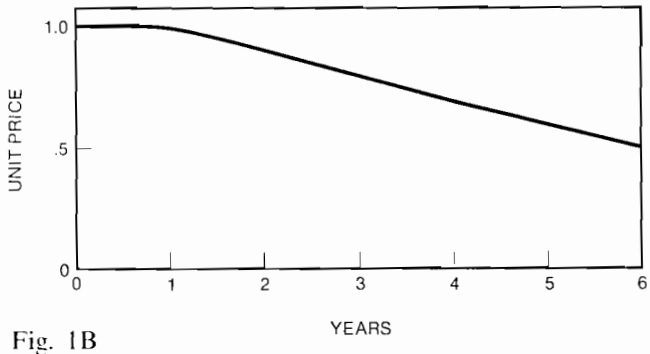

Fig. 1B

FIGURE 1—Early Product Introduction Increases Sales

petitive situation when one company beats the other to the market. Assuming both companies have about the same marketing capability, the company which introduces the first product usually can gain a greater share of the market. The first product reaches a mature sales volume more quickly as well. This is illustrated in Fig. 1A. Fig. 1B shows the characteristic price erosion which occurs in many products during their life cycle. This price erosion means that the first company which introduces the product will not only sell more but will sell it at a higher price. In this hypothetical case, the first product to the market generates about twice the total income that the second product does. This is shown in TABLE V. In a case such as this, the advantage afforded by the application of a microcomputer is quite large. The benefits of early product introduction can be far more important to many companies than a reduction in actual manufacturing cost.

High Product Prices Due to Enhanced Product Capability

As has been discussed earlier, product features can be easily added to microcomputer systems by simply adding more program storage. Many microcomputer users have utilized this characteristic of microcomputers as a way of increasing the value of their product without significantly adding to the cost of the product. Examples of such easily added features are: putting automatic tax computations into a cash register by adding more ROM, adding automatic calibration features to instruments, and making traffic light controllers that automatically sense traffic load and adjust the duration of the signals, etc.

The microcomputer offers the designer a way to add

EFFECT ON SALES

FIRST PRODUCT ANNOUNCED

YEAR	PRICE	UNIT SALES	DOLLARS
1	1	.25	.25
2	.9	1.0	.9
3	.8	1.0	.8
4	.7	.75	.515
5	.6	.25	.150
		TOTAL	2.615

SECOND PRODUCT ANNOUNCED

YEAR	PRICE	UNIT SALES	DOLLARS
1	1	0	0
2	.9	.25	.225
3	.8	.75	.6
4	.7	.50	.350
5	.6	.10	.06
		TOTAL	1.235

TABLE V—Income For First And Second Product Introduced

significant features to systems at trivial costs. Marketing departments have seized this situation as an opportunity to raise product prices and increase corporation profits. It is not unusual to find many system products with base prices about two times the manufacturing cost. Optional features which many customers request are frequently sold at 10 to 20 times the cost of adding them to a system. Companies have been able to turn marginal products and services into real profit opportunities through the application of microcomputers.

Service and Warranty Costs

Because the microcomputer eliminates many ICs and consequently the failures associated with these devices, microcomputers can significantly increase system reliability. Most of the failures in a digital system occur because an interconnect has failed. The use of a typical 16 pin IC will introduce approximately 36 interconnectors in a system. There are 16 interconnections from the chip to the lead frame, 16 from the lead frame to the PC card and approximately 2 interconnections from the PC card to the back plane, and 2 interconnections from back plane point to back plane point per IC. If one ROM eliminates fifty ICs, then it eliminates approximately 1800 interconnections. While little data exists to prove the point, it is believed that the reliability of the electronic portion of a system can be increased by a factor of 5 to 10 through the use of microcomputers.

Today much complex electronic equipment is serviced on-site. A single service call frequently ends up costing 100 to 200 dollars. The elimination of one such service call every two years would save many companies enough money to buy the microcomputer they are using in their system.

Microcomputers Can Affect Product Line Profits

TABLE VI presents a comparison of the profit and loss statements of a hypothetical product line before and

	WITHOUT MICROCOMPUTER		WITH MICROCOMPUTER	
SALES		100%		100%
COST OF GOODS SOLD		55%		45%
GROSS MARGIN		45%		55%
DEVELOPMENT				
ENGINEERING	8		6	
DOCUMENTATION	1.5		1	
	9.5		7.0	
WARRANTY	1.5		1.0	
MARKETING	20.0		20.0	
G & A	3.0		3.0	
		34%		31%
BEFORE TAX PROFIT		11%		24%

TABLE VI—How Microcomputers Affect Corporate Profits

after the use of microcomputers. These statements are once again estimates based on input gathered from customers. They are at best approximate but are by no means optimistic.

The product line using the microcomputer is shown as having a smaller cost of goods sold. There are two reasons for this: (1) The manufacturing costs of systems containing a microcomputer are generally less than those implemented from conventional ICs, and (2) The enhanced capability of many microcomputer system products enables manufacturers to generate more income. Both these points have been discussed earlier. The shortening of development cycles and the elimination of much documentation which is produced during this time can save a company on the order of 2.5%. Warranty and service costs such as those associated with stocking-spares and training service engineers can be greatly reduced. The net effects of all these savings can frequently increase product line profits on the order of 10 to 20%.

Conclusion

Microcomputers represent a new and exciting advance in the state of the art. They have reduced the cost of putting basic computation into a device by a factor of 10 or more. As such they can bring to many new systems the benefits of using computers. Because of their small size and small cost, microcomputers can be designed into many devices such as cash registers, scales, stoplights, instruments, etc., where the use of a computer was once unthinkable.

The benefits of putting a computer into a system go far beyond the advantages of merely being able to include computation or decision making into the device being designed. As previously indicated, the use of a microcomputer can affect such basic things as manufacturing cost, market share, development costs and time, and system reliability and serviceability. Microcomputers are a new and exciting technology, however they are a technology with far-reaching implications. Their use can create a market lead or cut product line costs. As such, they are a tool for generating new corporate opportunities and profits.